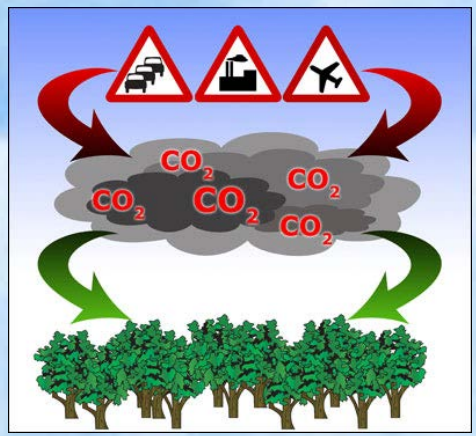

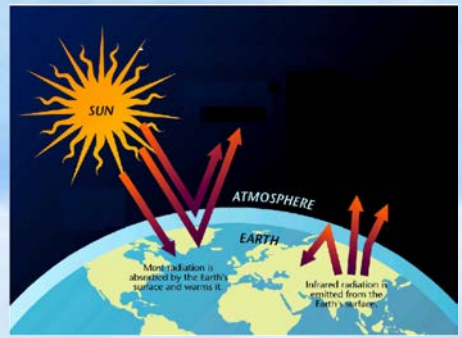

Energy, Carbon dioxide and Climate Change

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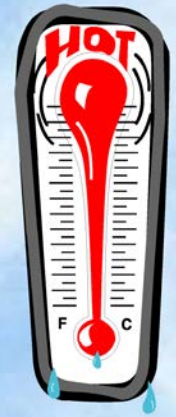
Upton NY USA

Emeritus Faculty Association

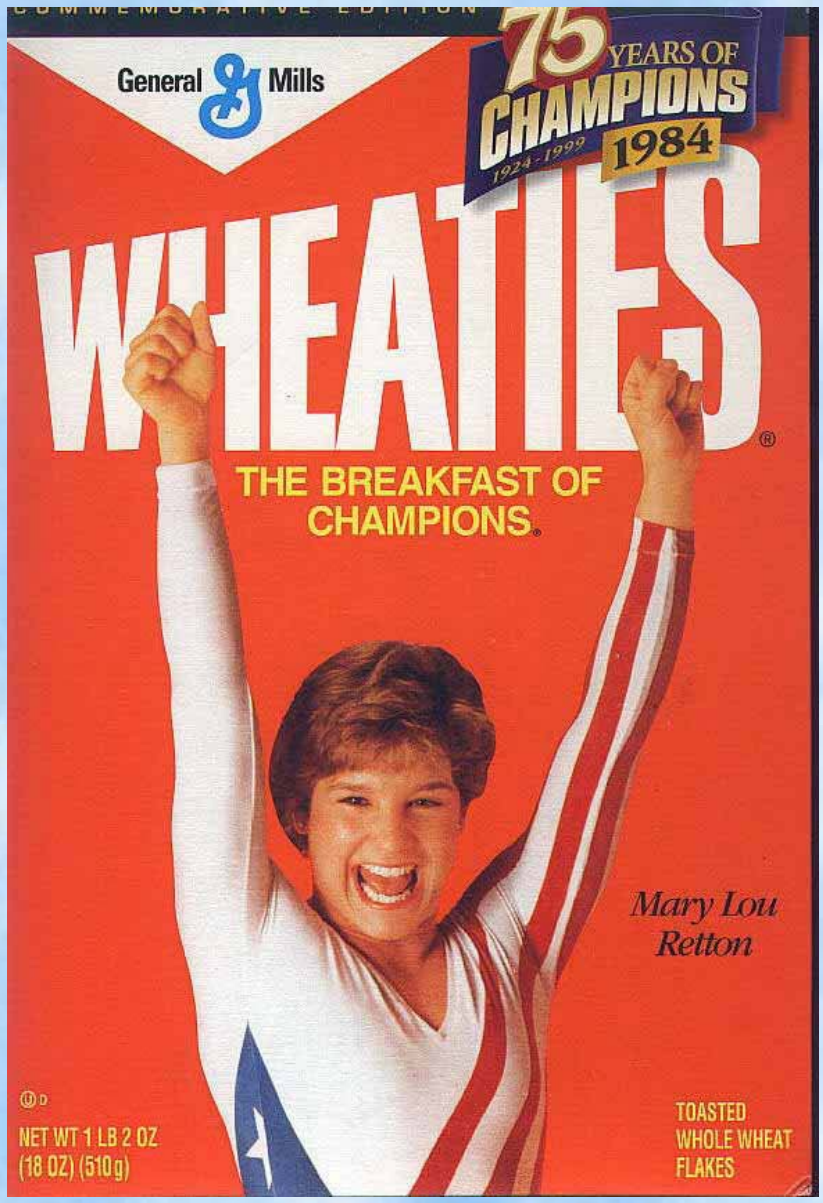
of the State University of New York at Stony Brook

April 5, 2013

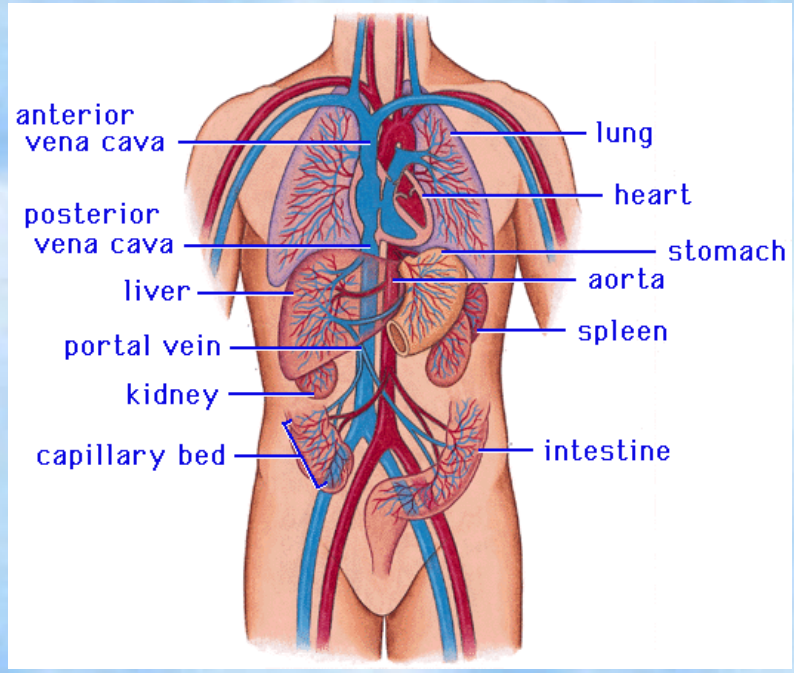
www.ecd.bnl.gov/steve

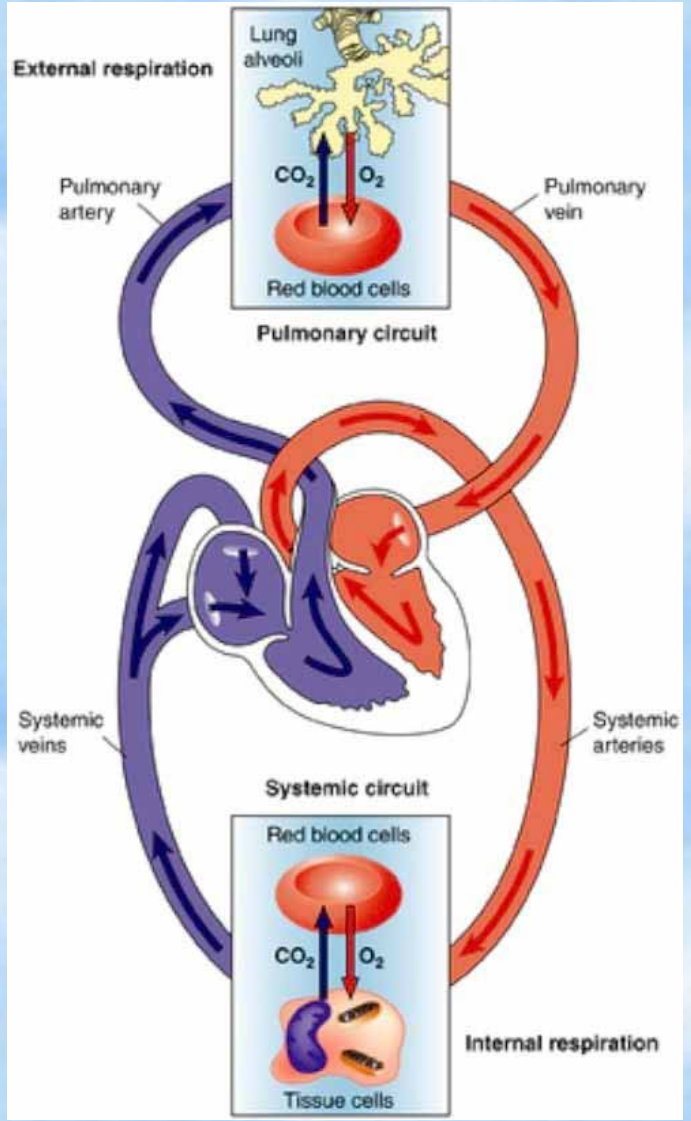


WHERE DO YOU GET YOUR ENERGY?



HOW DO ENERGY AND OXYGEN GET TO YOUR MUSCLES?

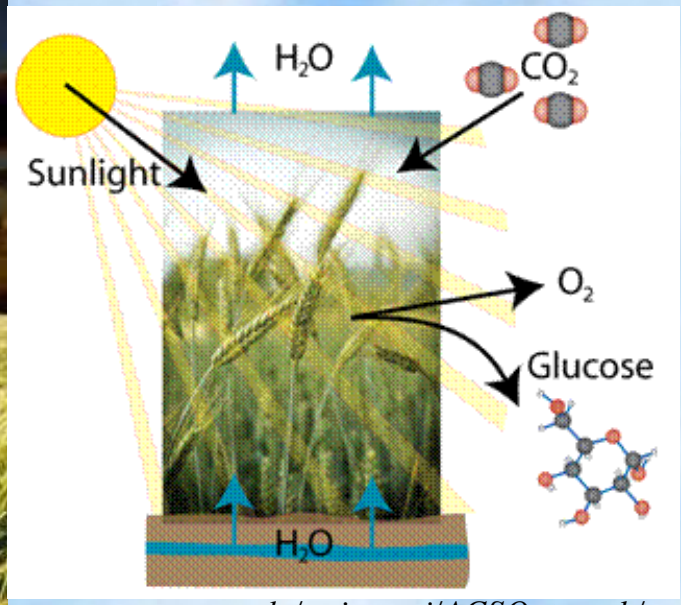




http://www.prevent-stroke-and-heart-attack.com
http://library.thinkquest.org/5777/cir1.htm
http://newstt.com/how-is-circulatory-system-and-the-digestive-system-related/

WHERE DOES YOUR FOOD GET *ITS* ENERGY?

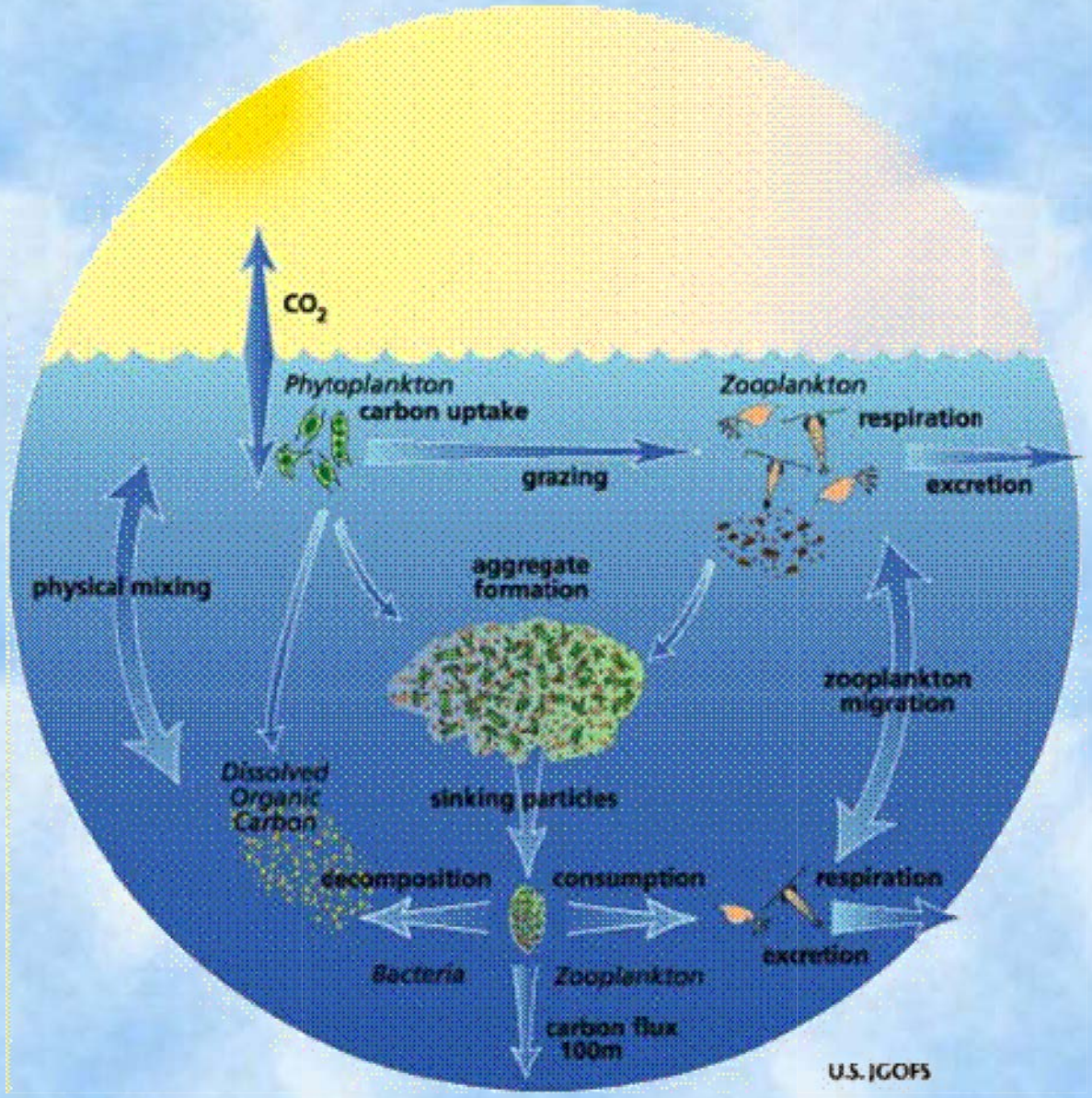
www.desktopwallpaperhd.com

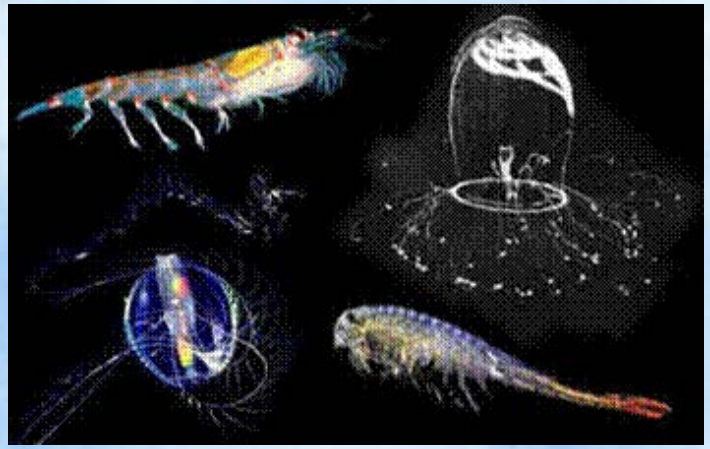


www.ems.psu.edu/~pisupati/ACSOutreach/Petroleum_1.html

WHERE DOES YOUR CAR GET *ITS* ENERGY?

WHERE DOES GASOLINE GET *ITS* ENERGY?



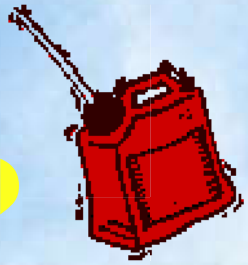


HOW MUCH CARBON IS IN A GALLON OF GASOLINE?

1 lb?

2 lbs?

3 lbs!?



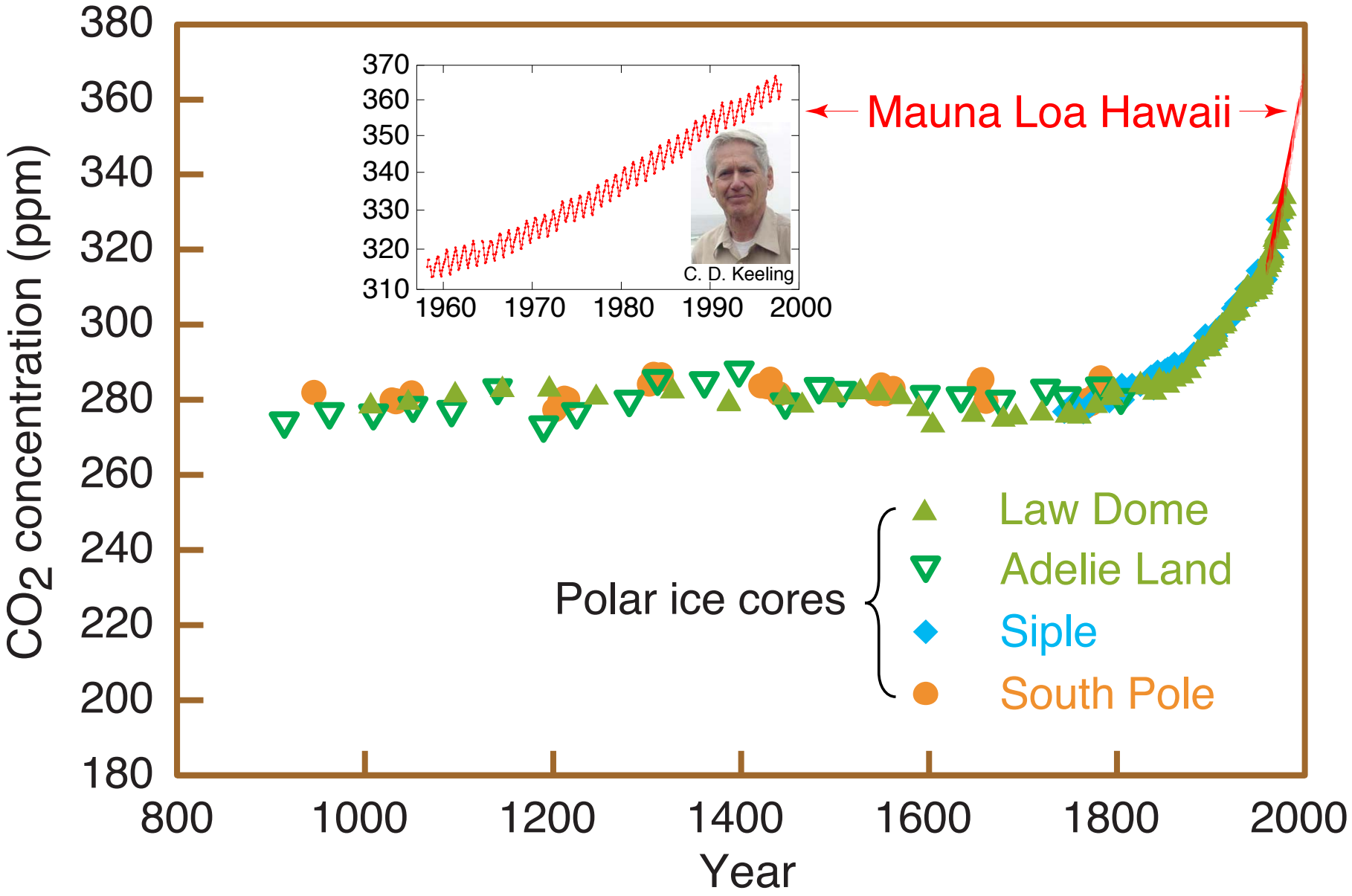
5 lbs!?!

All of this carbon goes into the atmosphere as carbon dioxide when you burn the gasoline in your car.

There's one law that even the Congress of the United States can't repeal . . .

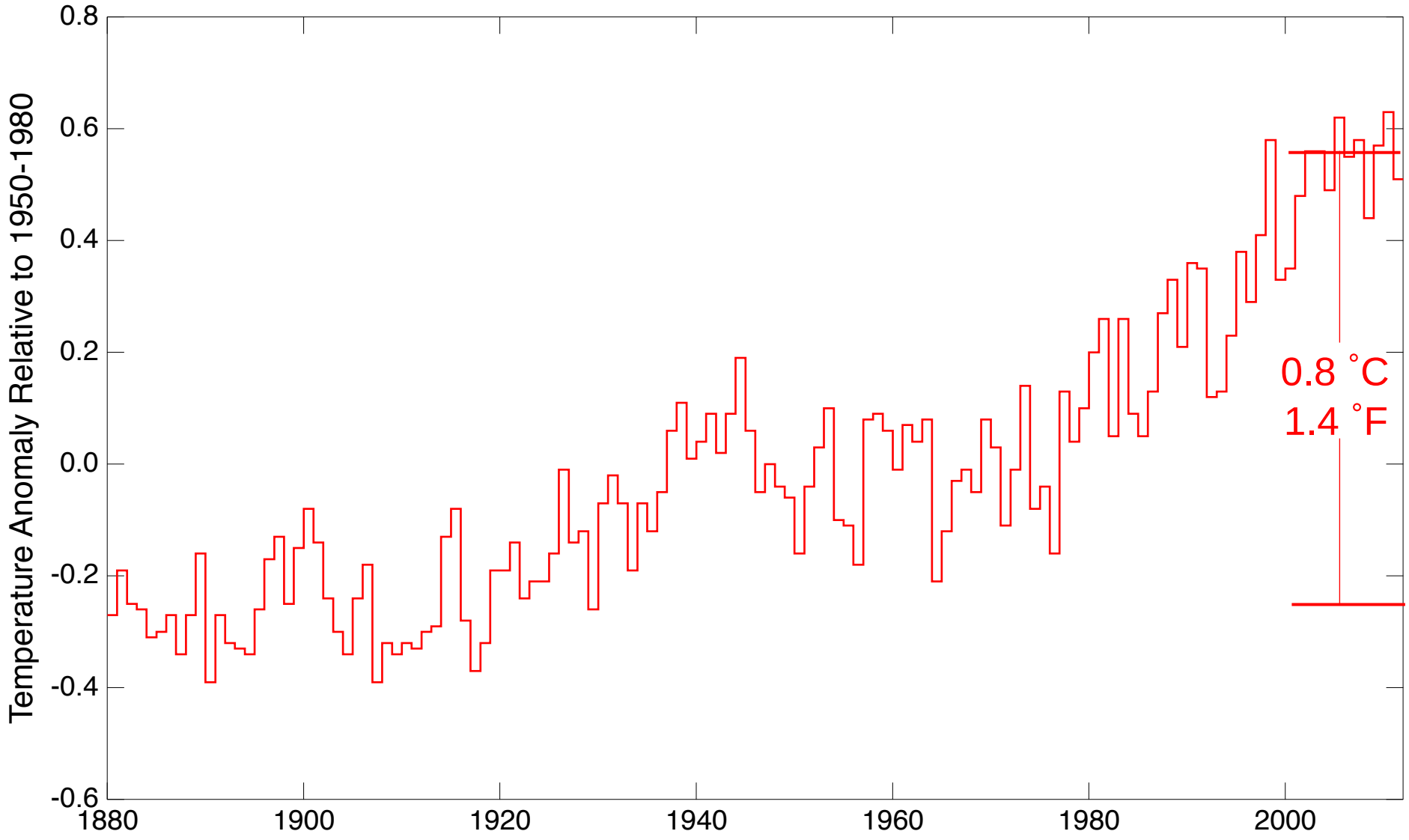
The law of conservation of matter.

ATMOSPHERIC CARBON DIOXIDE IS INCREASING

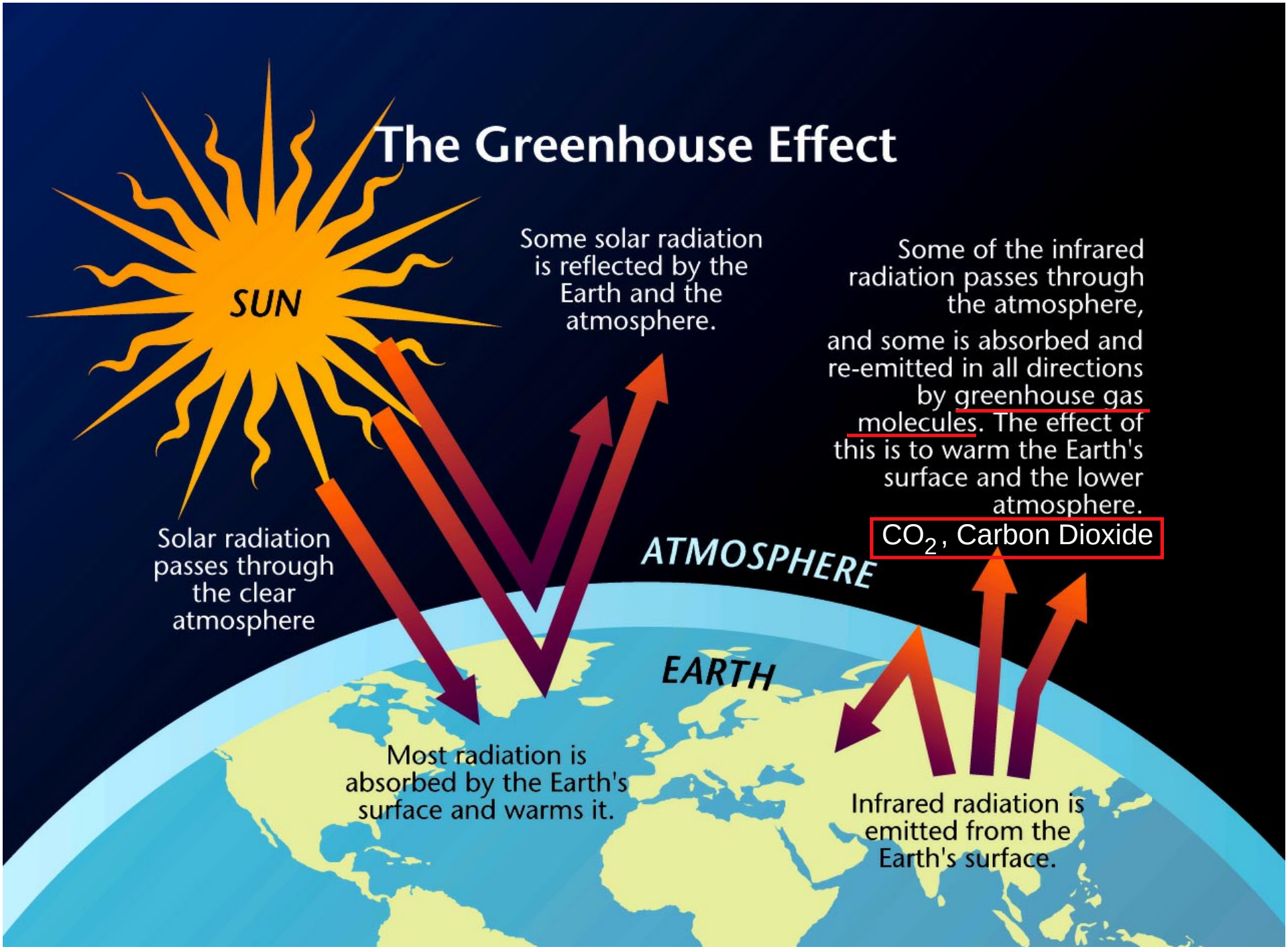


Global carbon dioxide concentration over the last thousand years

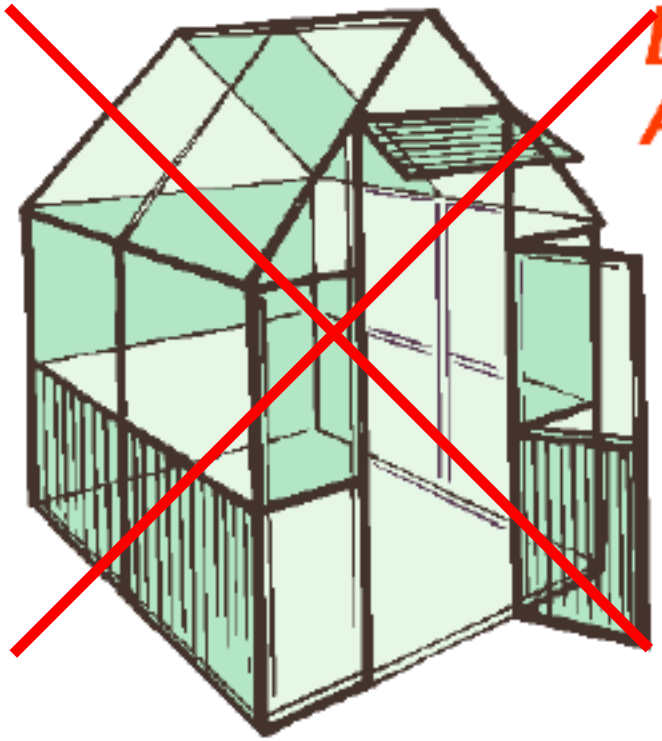
GLOBAL TEMPERATURE OVER PAST 130 YEARS



NASA Goddard Institute for Space Studies


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere,
and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
CO_2, Carbon Dioxide
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

THE GREENHOUSE EFFECT



EARTH'S ENERGY BUDGET: A DELICATE BALANCE

- Sunlight heats the Earth.
- The warm Earth radiates energy (in the form of infrared radiation, or heat) back out to space.
- Some of this infrared radiation is trapped in the atmosphere, giving Earth its temperate climate.

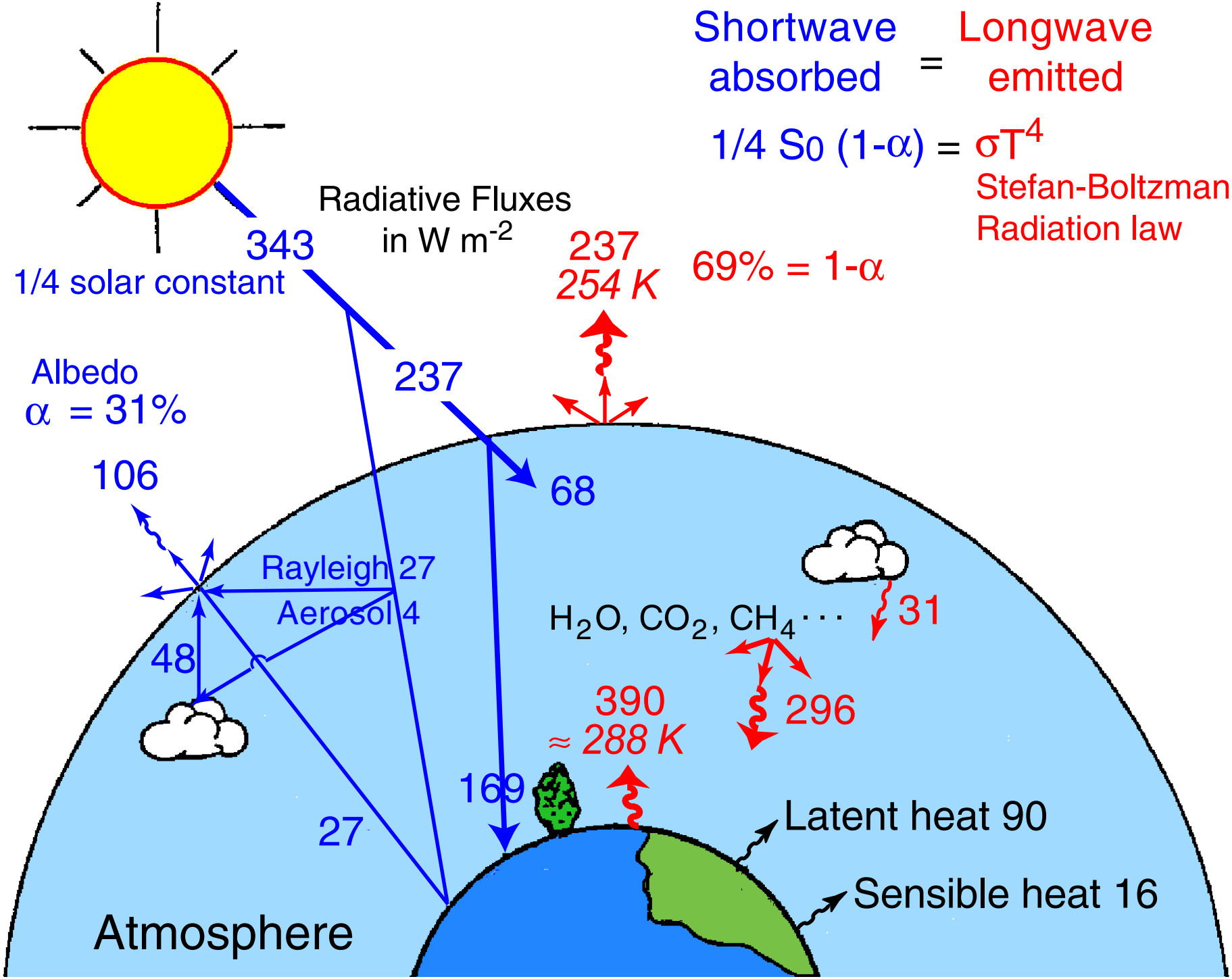
This is the greenhouse effect.

Global average temperature 15°C or 59°F

Without it, the Earth's climate would be like the moon's, harsh and severe.

Global average temperature -19°C or -2 °F

EARTH'S RADIATION BUDGET AND THE GREENHOUSE EFFECT



Modified from Schwartz, 1996; Ramanathan, 1987

ATMOSPHERIC RADIATION

Power per area

Energy per time per area

Unit:
Watt per square meter
W m^{-2}

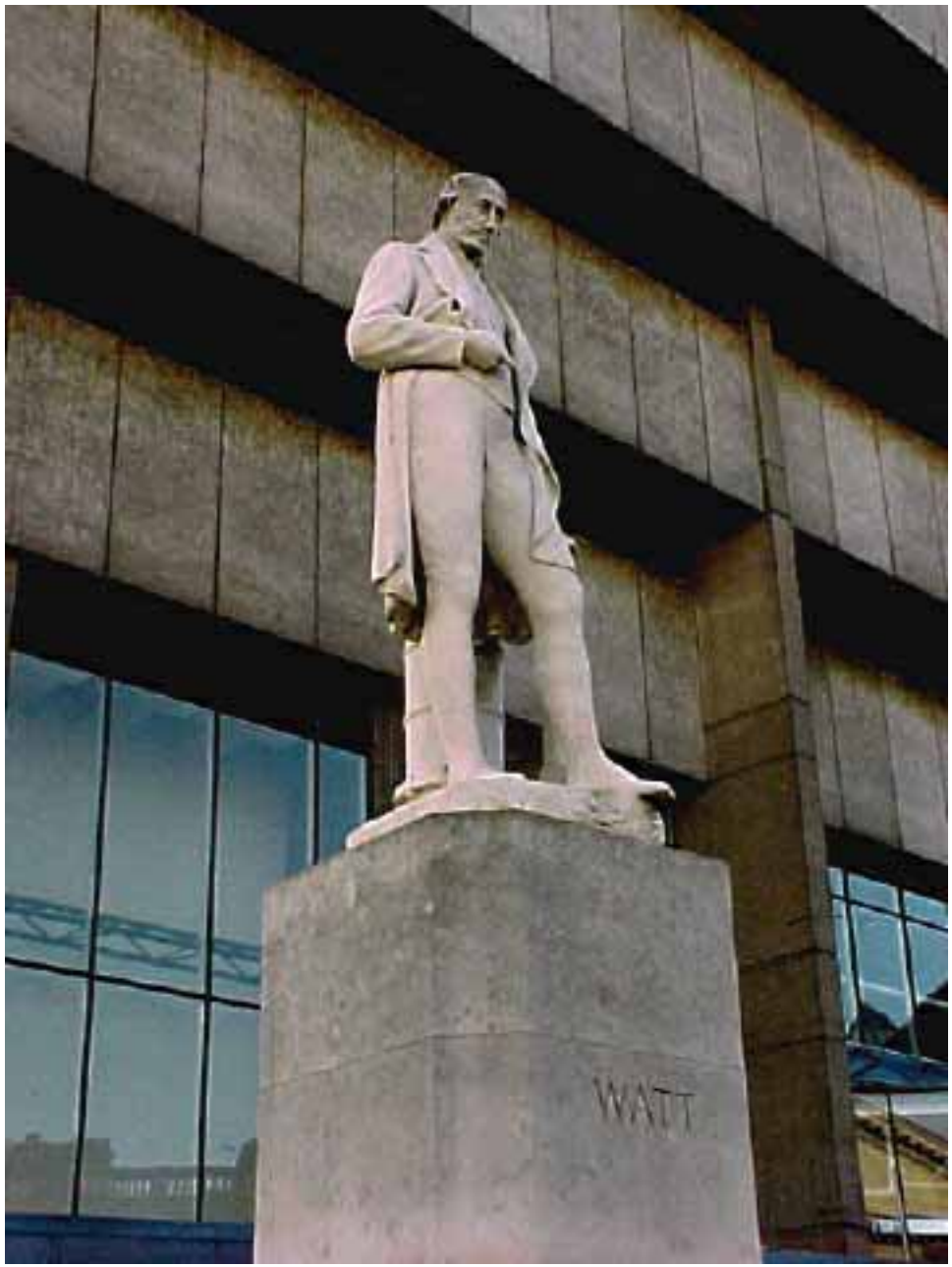


Photo credit: S. E. Schwartz

RADIATIVE FORCING

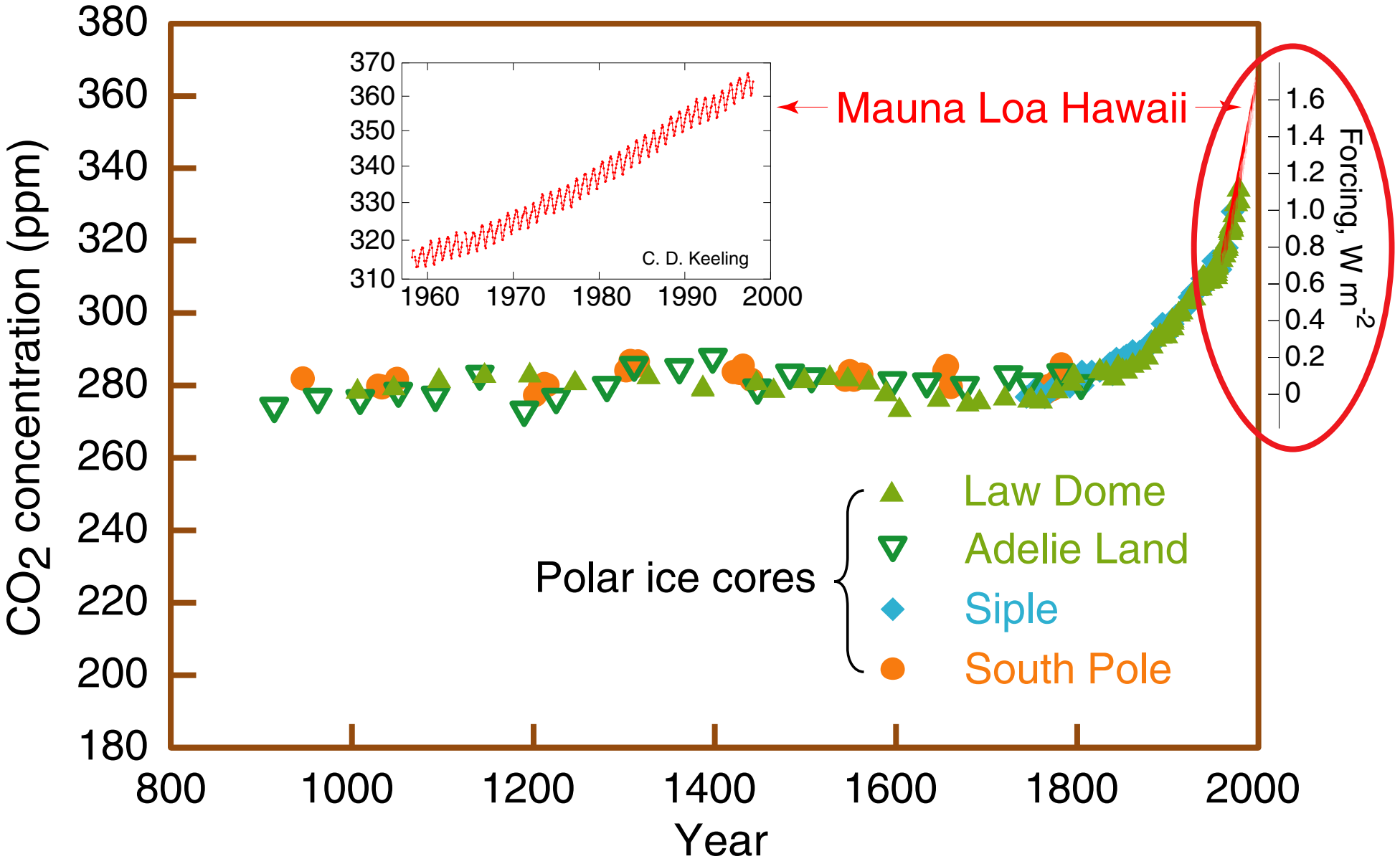
An externally imposed ***change*** in Earth's radiation budget, W m^{-2}.

Working hypothesis:

On a global basis radiative forcings are additive and interchangeable.

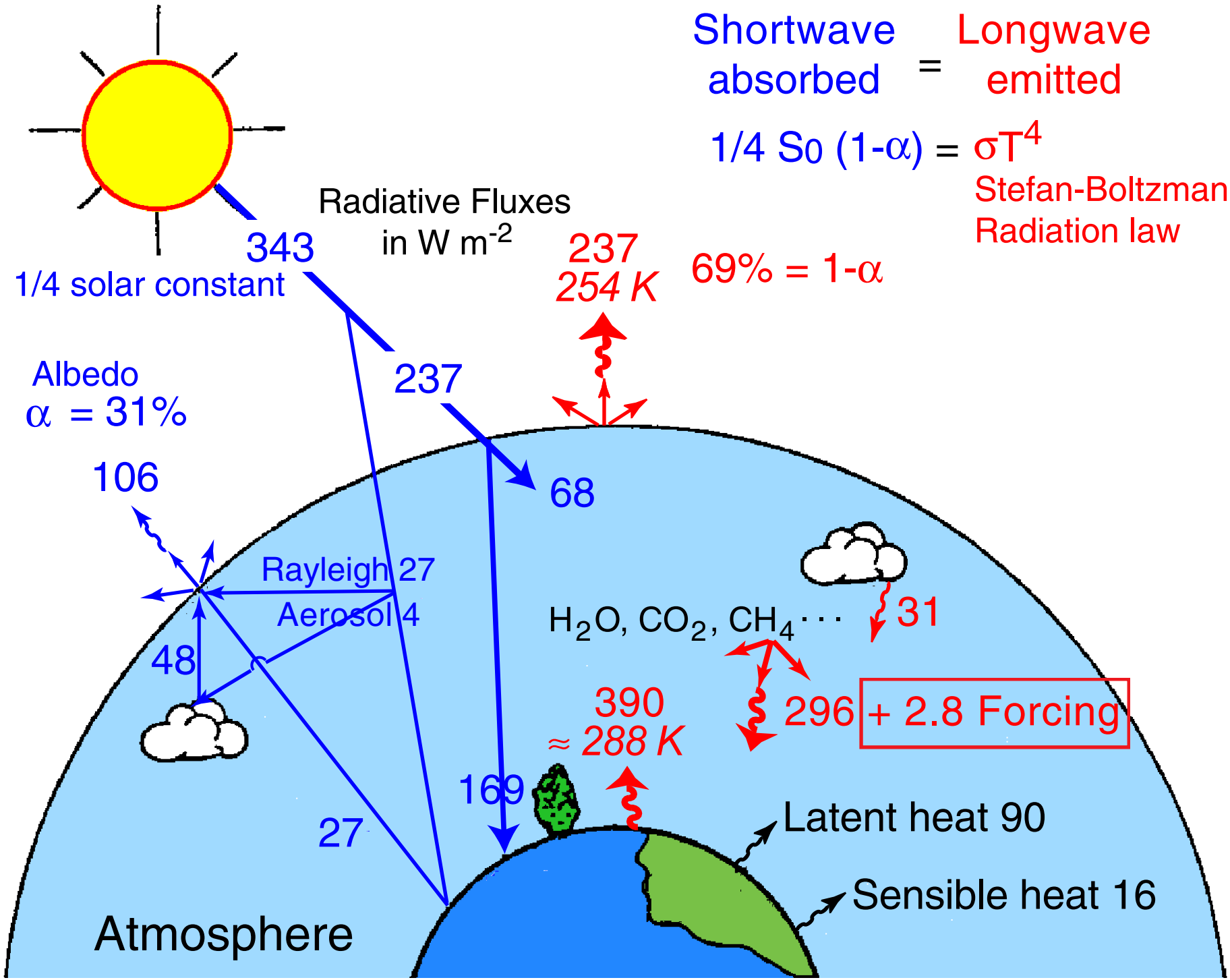
- This hypothesis is fundamental to the radiative forcing concept.
- This hypothesis underlies much of the assessment of climate change over the industrial period.

ATMOSPHERIC CARBON DIOXIDE IS INCREASING



The increase in CO_2, a greenhouse gas, has produced a radiative forcing which is now 1.7 W m^{-2}.

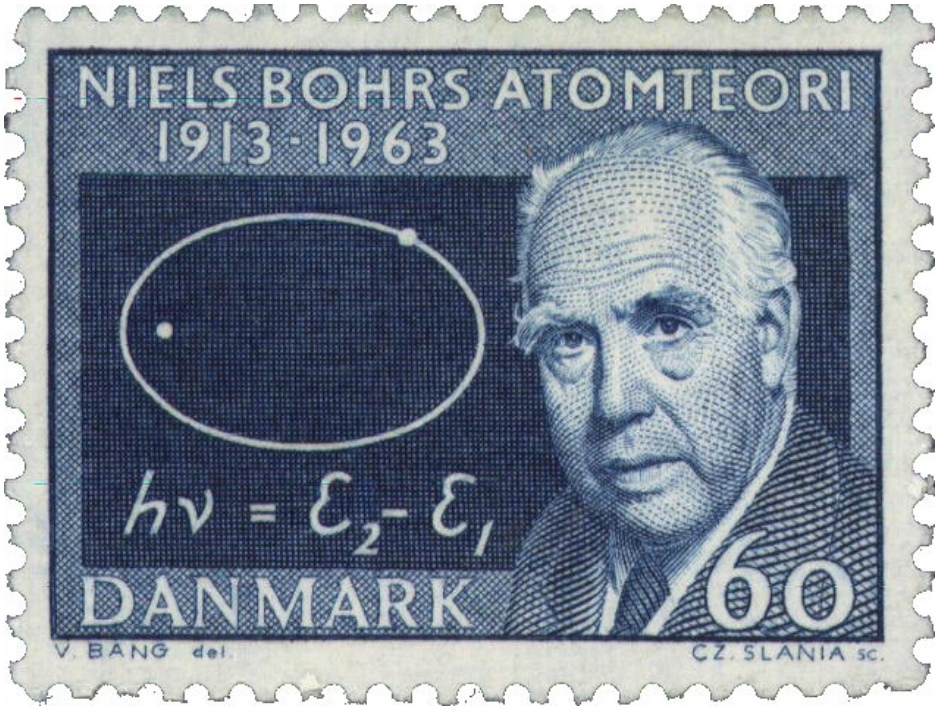
EARTH'S RADIATION BUDGET AND THE GREENHOUSE EFFECT



Modified from Schwartz, 1996; Ramanathan, 1987

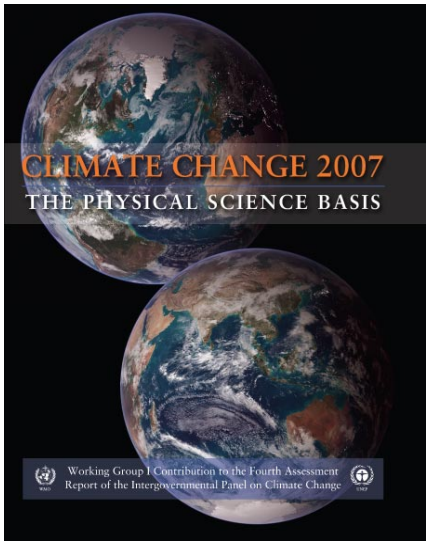
Looking to the Future . . .

Prediction is difficult,
especially about the future.



– Niels Bohr

THE BIBLE OF CLIMATE CHANGE



It's big and thick.

Every household should have one.

No one reads it from cover to cover.

You can open it up on any page and find something interesting.

It was written by a committee.

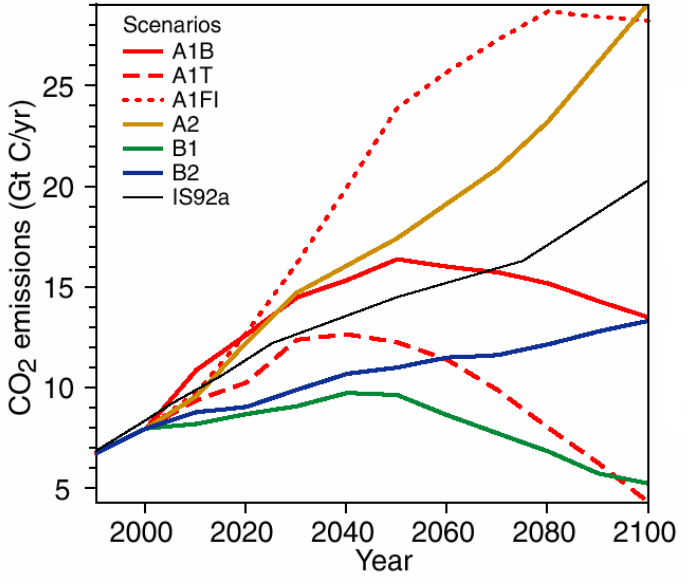
It is full of internal contradictions.

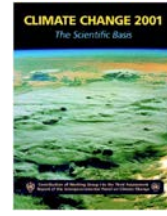
It deals with cataclysmic events such as floods and droughts.

It has its true believers and its skeptics.

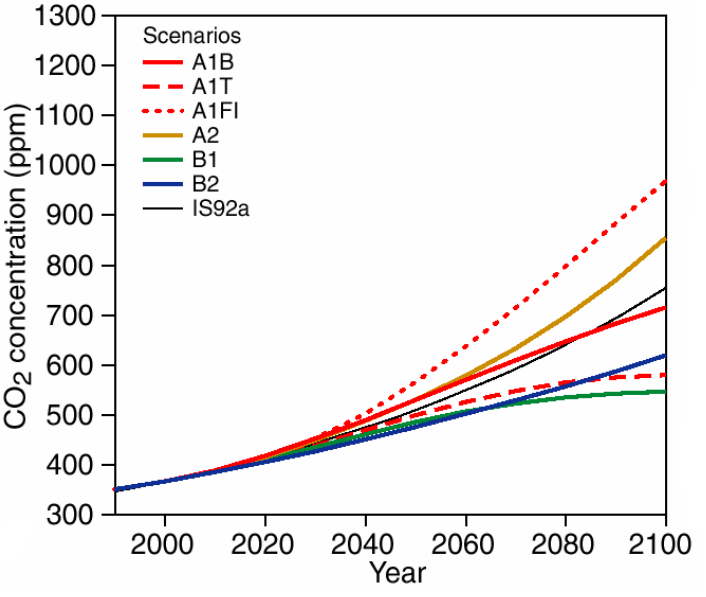
It can be downloaded off the internet for free.

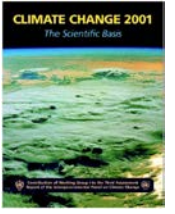
PROJECTIONS OF FUTURE CO2 EMISSIONS





PROJECTIONS OF FUTURE CO2 CONCENTRATIONS





FIRST PRINCIPLES CLIMATE MODELING

Approach

Understand the processes controlling climate and climate change.

Represent these explicitly in computer models.

Improve resolution (spatial, process) until the model provides a sufficiently accurate representation.

Evaluate model by comparison with observations.

Product

Predictive capability; ability to project the ***many consequences*** of various hypothetical external perturbations.

Modeled changes in quantities of interest for various "what if?" scenarios.

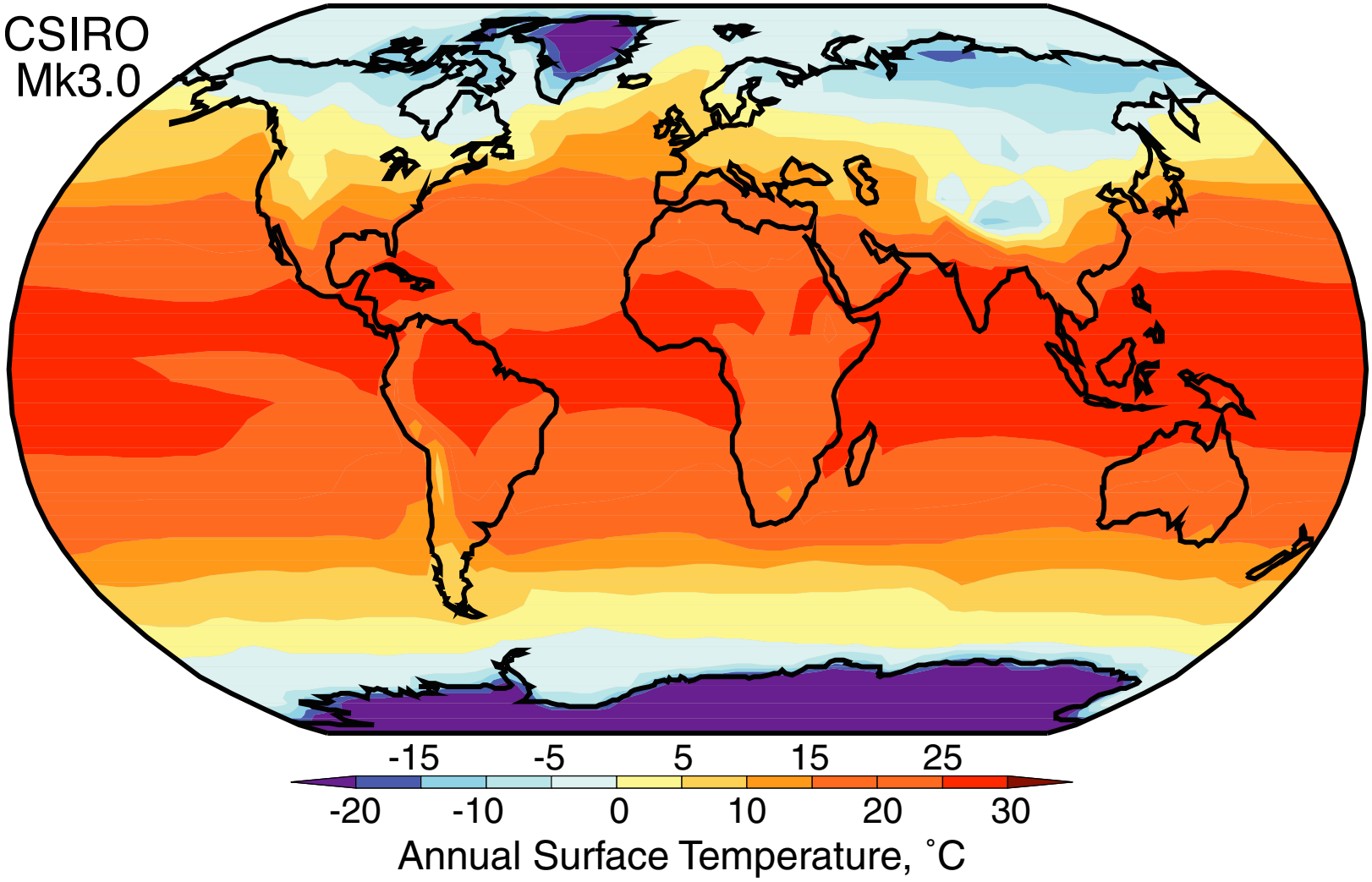
Concerns

Accuracy. The model must be sufficiently accurate that the consequences of small perturbations can be determined with confidence as the ***difference with and without the perturbation***.

Sensitivity to processes that are not well understood or represented.

ANNUAL MEAN SURFACE TEMPERATURE

Calculated with Global Climate Model



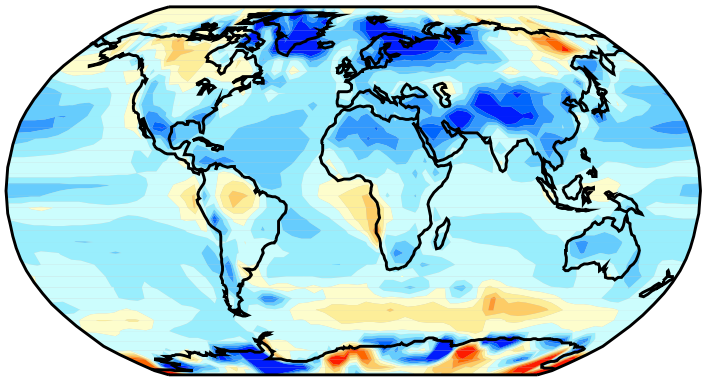
IPCC, 2007, Chapter 8, Suppl.

Model output is richly detailed. Overall pattern is quite good, given that ***the entire climate system is modeled from first principles***.

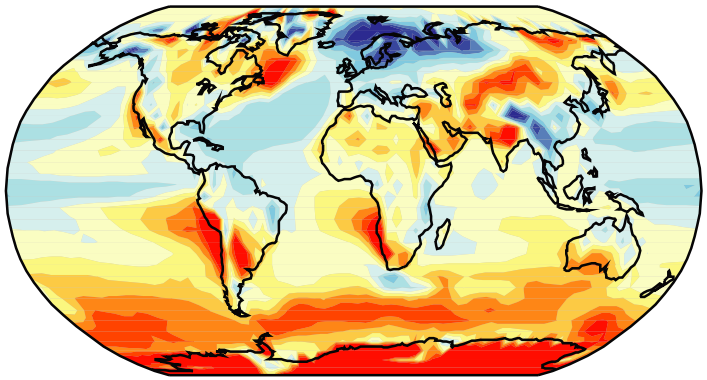
ANNUAL MEAN SURFACE TEMPERATURE

Difference from observations, calculated with Global Climate Model

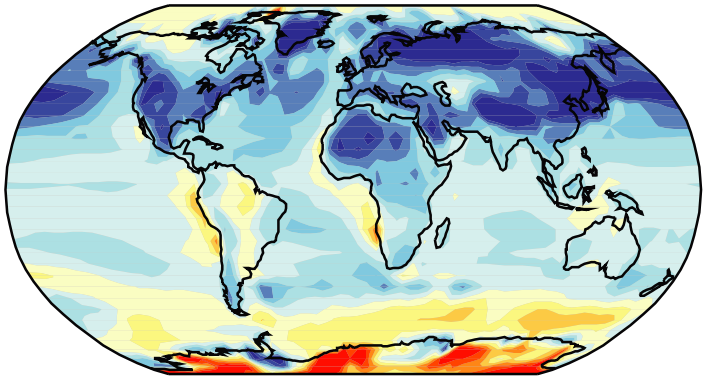
CSIRO-Mk3.0



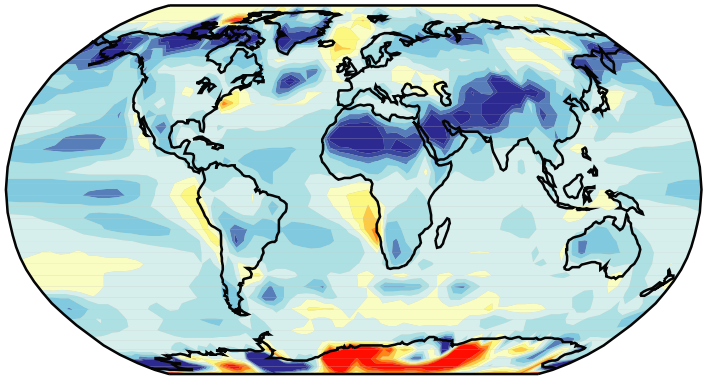
GISS-EH

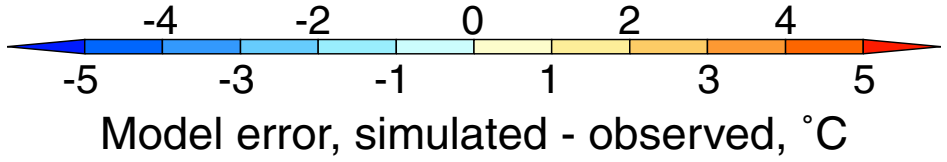


GFDL-CM2.0



UKMO-HadGEM1



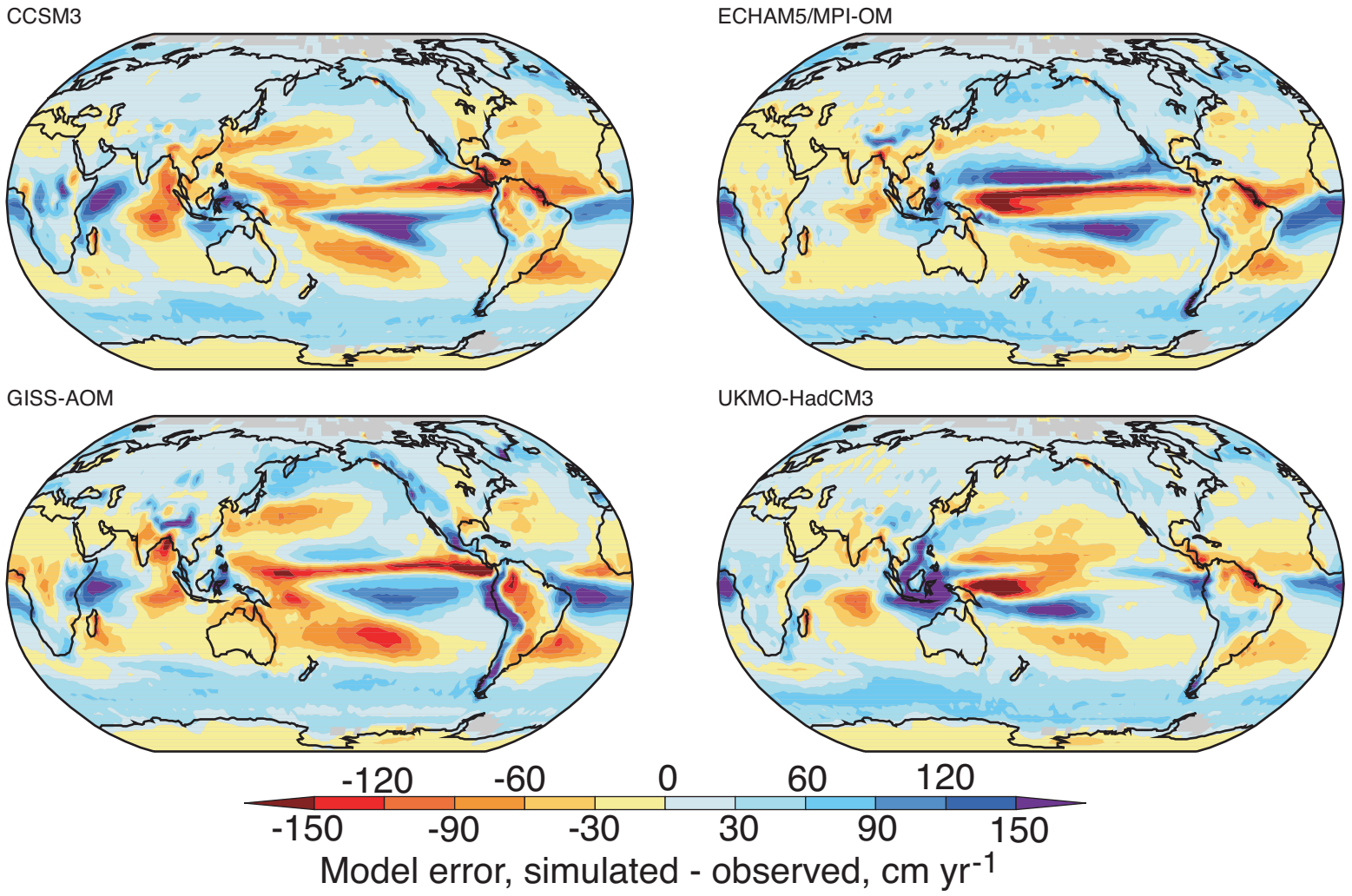


IPCC, 2007, Chapter 8, Suppl.

Accuracy is quite good as a fraction of 288 K, but differences are climatologically significant and exceed expected warming.

ANNUAL MEAN PRECIPITATION

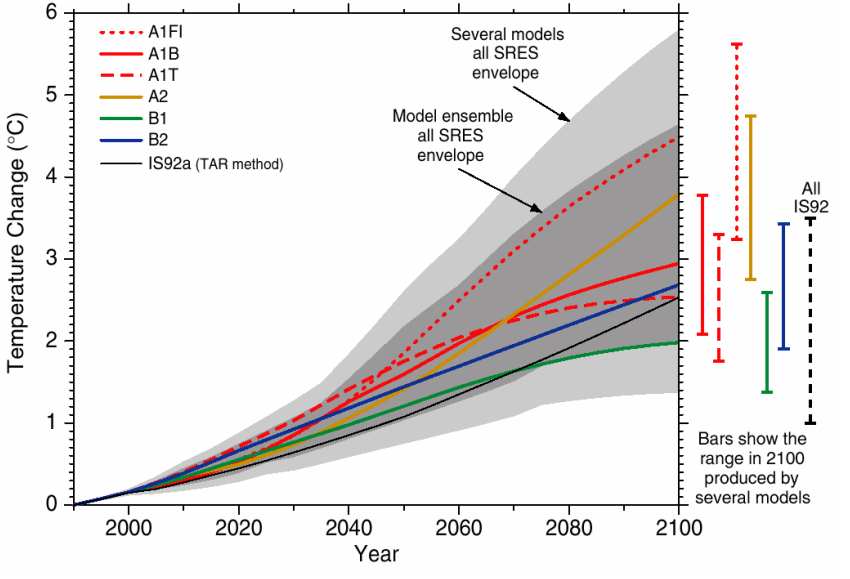
Difference from observations, calculated with Global Climate Models

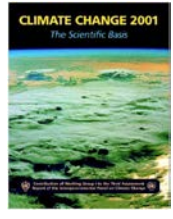


IPCC, 2007, Chapter 8, Suppl.

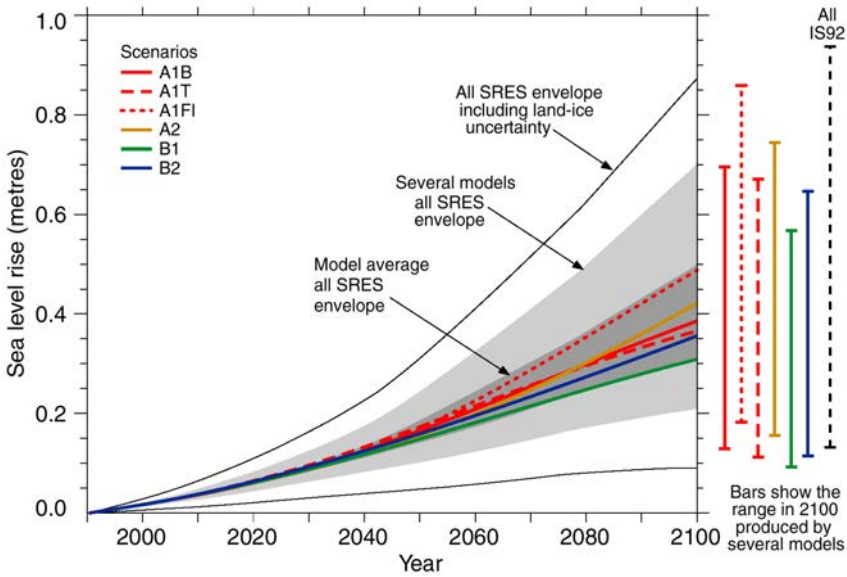
Departure from observations and model-to-model differences are substantial in some locations.

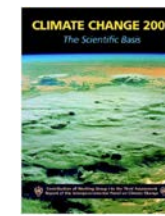
PROJECTIONS OF FUTURE TEMPERATURE CHANGE



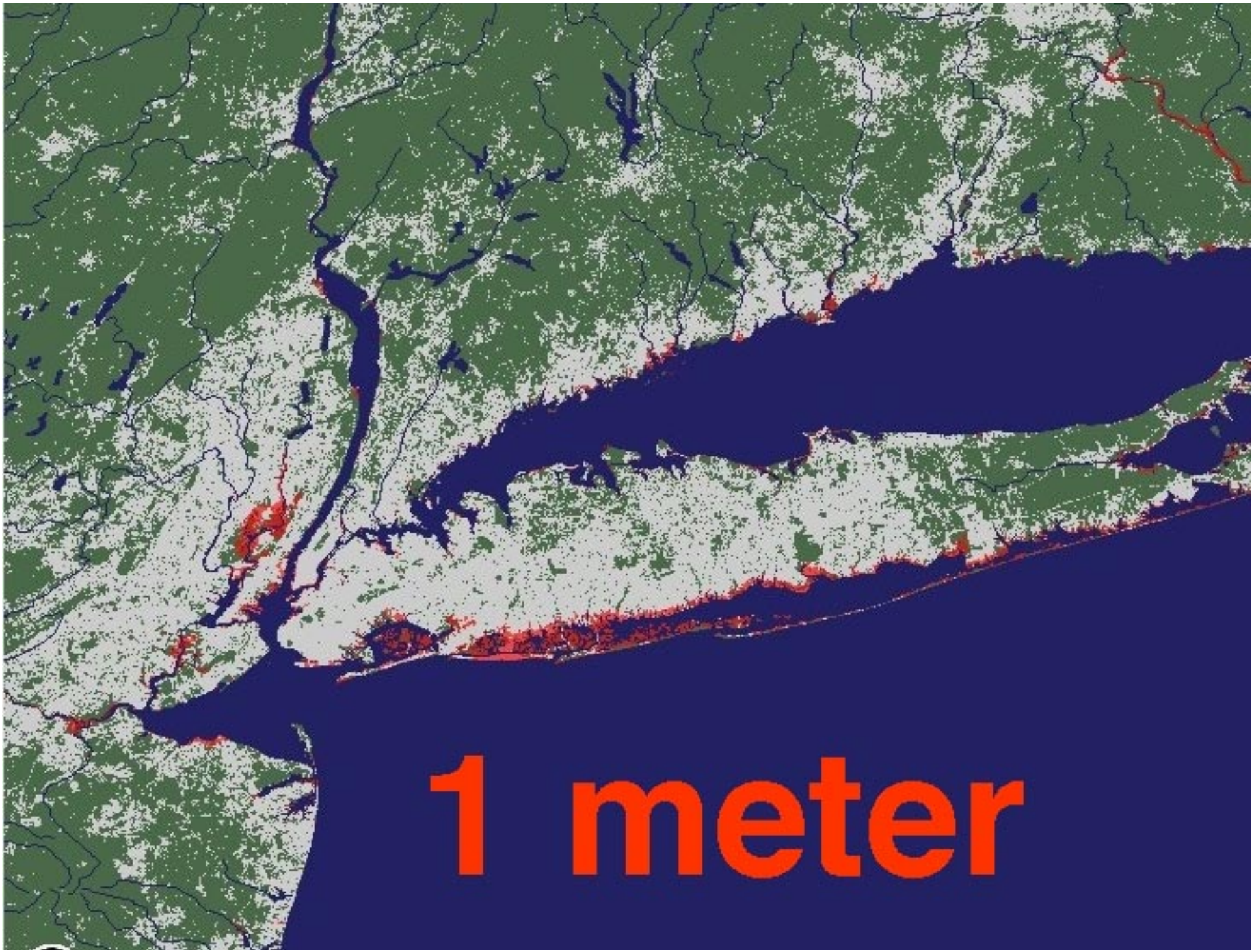


PROJECTIONS OF FUTURE SEA LEVEL RISE



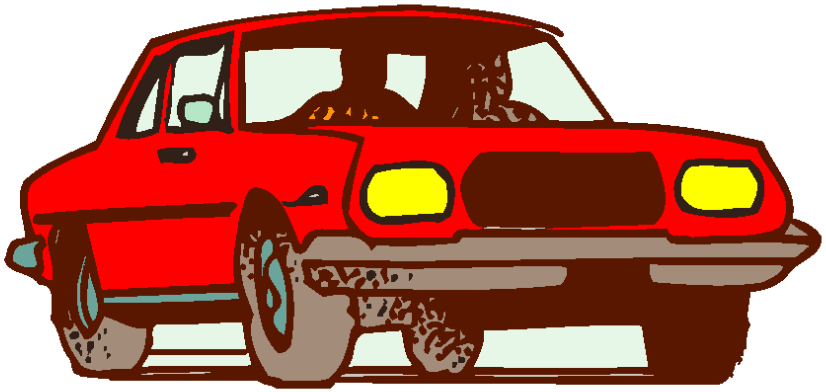



present


1 meter

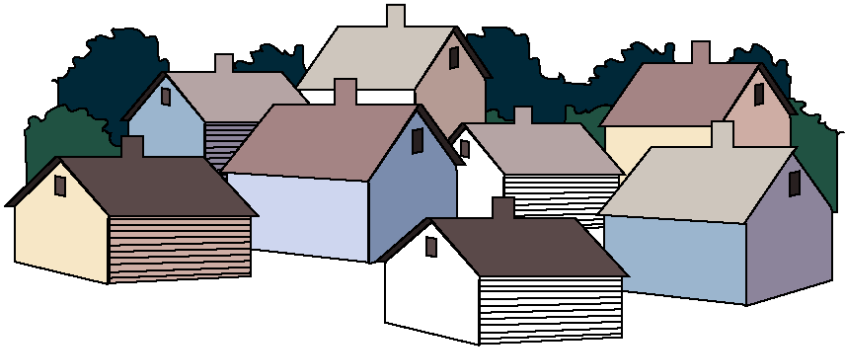
WHERE IS THIS CARBON DIOXIDE COMING FROM?

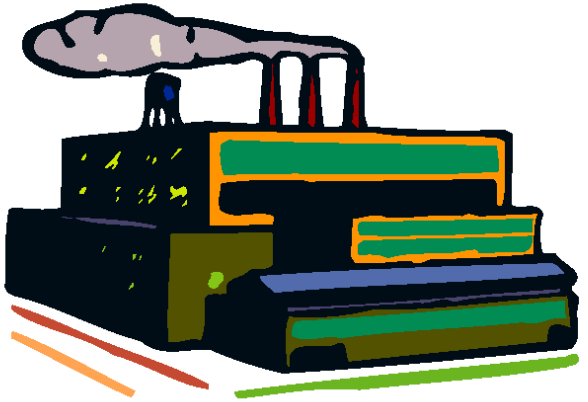
WE ARE ALL RESPONSIBLE.



Burning a gallon of gasoline in your car puts 5 pounds of carbon in the atmosphere as carbon dioxide (CO_2), and it will stay there for decades — maybe a century!

Other sources are home heating and electric power production.





ENERGY EFFICIENT CARS

Decrease your carbon legacy by driving an energy efficient car

Decrease your gasoline bill, and drive in HOV lane, too!

SOLAR PHOTOVOLTAIC ENERGY

Decrease your carbon legacy by generating your own electricity

Decrease your electric bill, too; maybe even to zero!

Global Atmosphere, Global Warming

QUESTIONS ABOUT GLOBAL WARMING

- IS IT REAL?
- IS IT IMPORTANT?
- WHAT IS IT DUE TO?
- HOW MUCH MORE CAN WE EXPECT?
- ARE WE SEEING JUST THE TIP OF THE ICEBERG?

RESEARCH IS HELPING TO ANSWER THESE QUESTIONS.

www.ecd.bnl.gov/steve